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7.0 STEAM AND POWER CONVERSION SYSTEM

Learning Objectives:

1. State the purposes, and describe the operation, of the main steam supply system.

2. State the purposes, and describe the operation, of the condensate and feedwater system.

3. State the purpose, and describe the operation, of the condenser circulating water system.

4. State the purposes, and describe the operation, of the emergency feedwater system.

5. Describe the major differences between the design of the US-APWR steam and power conversion system and those of currently operating PWRs.

7.1 General Description

The steam and power conversion system is designed to remove heat energy from the reactor coolant system via the four steam generators and to convert it to electrical power in the turbine-generator. The steam generated in the four steam generators is supplied to the high pressure turbine by the main steam system. After expansion through the high pressure turbine, the steam passes through the two moisture separator reheaters (MSRs) and then into the three low pressure turbines. A portion of the steam is extracted from the high and low pressure turbines for seven stages of feedwater heating.

Exhaust steam from the low pressure turbines is condensed and deaerated in the main condenser. The heat exhausted in the main condenser is removed by the circulating water system (CWS). The condensate pumps take suction from the condenser hotwell and deliver the condensate through four stages of low pressure shell-and-tube feedwater heaters to the fifth-stage, open, deaerating heater. Condensate then flows to the suctions of the steam generator feedwater booster pumps, and the booster pump discharge flows to the suctions of the main feedwater pumps. The steam generator feedwater pumps discharge the feedwater through two stages of high pressure feedwater heaters to the four steam generators.

The moisture separator drains are sent to the deaerator. The reheater drains are sent to the high pressure feedwater heaters, and the high pressure feedwater heater drains are cascaded into the deaerator. Drains from the low pressure feedwater heaters are cascaded through successively lower pressure feedwater heaters to the heater drain tank and then pumped by the heater drain pumps to the piping between the first- and second-stage low pressure heaters.

The turbine-generator has an output ranging from 1600 MWe to 1700 MWe, depending on the plant conditions, for the Mitsubishi Heavy Industries (MHI) nuclear steam supply system (NSSS) thermal output of 4,466 MWt. The principal turbine-generator and rated NSSS performance characteristics are listed in Table 7-1.

Figure 7-1 depicts a conceptual overall system flow diagram.

In the event of a turbine trip, steam is bypassed to the condenser via the turbine bypass valves or, if necessary, to the atmosphere via the air-operated relief valves. Steam relief permits energy removal from the reactor coolant system.

The emergency feedwater pumps provide feedwater to the steam generators for the removal of sensible and decay heat whenever main feedwater flow is interrupted, including when offsite electric power is lost.

7.2 Turbine-Generator

The turbine-generator (T/G) is an 1800-rpm tandem compound six-exhaust flow unit. The T/G train consists of one double-flow high pressure turbine, three double-flow low pressure turbines, and one generator. Two external MSRs providing two stages of reheating are located on each side of the T/G centerline. The single direct-driven generator is water cooled and rated at 1,900 MVA, 0.9 PF. Other related system components include a complete T/G bearing lubrication oil system, a digital electrohydraulic (DEH) control system with supervisory instrumentation, a turbine gland seal system, overspeed protective devices, a turning gear, a stator coil cooling water system, an H_2 & CO_2 gas control system, a seal oil system, a rectifier section, and a voltage regulator. The major design parameters of the T/G and associated auxiliaries are presented in Table 7-2.

The T/G does not serve a safety-related function and therefore has no nuclear safety design basis. The T/G could be a potential source of high energy turbine missiles, which could cause damage to safety-related equipment or systems. The turbine is designed to minimize the possibility of turbine missile generation. In addition, the T/G and associated piping, valves, and controls are located completely within the turbine building, where no safety-related systems or components are located. The probability of a destructive overspeed condition and missile generation, assuming the recommended inspection and test frequencies, is less than 1×10^{-5} per year in accordance with NUREG-800, SRP subsection 3.5.1.3. In addition, the orientation of the T/G is such that a high energy missile is expected to be directed at an approximately 90° angle away from safety-related structures, systems, and components. Failure of the T/G equipment does not preclude safe shutdown of the reactor.

Main steam from the steam generators (SGs) enters the high pressure turbine through four horizontally mounted main turbine stop valves (MTSVs) and four plug-type main turbine control valves (MTCVs). The function of the MTSVs is to quickly shut off the main steam flow to the turbine when the MTSVs receive a trip signal. The main function of the MTCVs is to regulate the main steam flow to the turbine. Each MTSV is in series with an MTCV, and two MTSV/MTCV pairs are grouped in each of two steam chambers. The steam chambers flank the high pressure turbine casing.

One pair of reheater stop and intercept valves (RSVs and IVs) is installed in each of six cross-over pipes from the external moisture separator reheaters to the low pressure turbines.

The generator is a direct-driven, 3-phase, 60-Hz, 1800-rpm, 4-pole synchronous generator with a water-cooled stator and a hydrogen-cooled rotor. The generator auxiliaries include a seal oil system, an H_2 & CO_2 gas control system, and a stator-coil cooling water system. The generator excitation is the static type.

7.3 Main Steam Supply System

The main steam supply system (MSS), depicted in Figure 7-2, directs steam from the steam generator outlet nozzles to the main turbine stop valves. The main function of the MSS is to transport steam from the SGs to the high pressure turbine and to the moisture separator reheaters over a range of flows and pressures covering the entire operating range from system warmup to valve-wide-open turbine conditions.

The system also supplies steam to the main turbine gland seal system, the emergency feedwater (EFW) pump turbines, the deaerator, and the auxiliary steam supply system (ASSS). The system also dissipates heat generated by the nuclear steam supply system by means of the turbine bypass valves (TBVs) to the condenser, or to the atmosphere through the air-operated main steam relief valves (MSRVs), motor-operated main steam depressurization valves (MSDVs), or spring-loaded main steam safety valves (MSSVs) when either the turbine-generator or the condenser is unavailable.

7.3.1 Design Bases

7.3.1.1 Safety-Related Design Bases

The system is provided with a main steam isolation valve (MSIV) and an associated main steam bypass isolation valve (MSBIV) in each main steam line. These valves isolate the secondary sides of the SGs to prevent the uncontrolled blowdown of more than one SG. MSIV and MSBIV closure also isolates the nonsafety-related portions of the system from the safety-related portions.

The following MSS components are classified as Equipment Class 2, are safety related, and are designed in accordance with American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section III, Class 2, Seismic Category I:

- All piping and valves from the SGs up to and including the MSIVs and MSBIVs,
- Branch lines from the above described main steam piping up to and including the first valve in each line, which includes the MSSVs,
- Inlet piping from the main steam lines up to and including the MSRVs and MSDVs,
- Branch lines from the main steam piping to the emergency feedwater pump turbines up to and excluding the first motor-operated valve in each line,

- Main steam drain piping upstream of the MSIVs up to and including the main steam drain line isolation valves (MSDIVs), and
- Nitrogen supply lines located on the main steam piping upstream of the MSIVs, up to and including the first isolation valve in each line.

The following MSS components are classified as Equipment Class 3, are safety related, and are designed in accordance with American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section III, Class 3, Seismic Category I:

- MSS piping downstream of each MSIV and MSBIV up to and including the first restraint located in the main steam/feedwater piping area,
- MSSV, MSRV and MSDV discharge piping located in the main steam/feedwater piping area, and
- Piping downstream of the MSDIVs and located in the main steam/feedwater piping area.

All remaining components located outside of the reactor building are not safety related, are not seismically qualified, and are designed in accordance with the Power Piping Code, ASME B31.

The safety-related portion of the MSS is designed to withstand the effects of a safe-shutdown earthquake (SSE) and to perform its intended functions following postulated events.

The safety-related portions of the MSS are designed to perform their required functions during normal conditions, adverse environmental occurrences, and accident conditions including the loss of offsite power with a single malfunction or failure of an active component.

The safety-related portions of the MSS are designed such that a single failure in the MSS does not result in:

- The loss of integrity of other steam lines,
- The inability of the engineered safety features to effect a safe shutdown, or
- The transmission of excessive loading to the containment pressure boundary.

The MSS includes the capability to operate the MSDVs remotely from the main control room following an SSE coincident with the loss of offsite power, so that a cold shutdown can be achieved by depending only on safety-grade components.

7.3.1.2 Power Generation Design Bases

The MSS is designed to deliver steam from the SGs to the turbine-generator for the range of flow rates, temperatures and pressures from warming of the main steam piping to rated power conditions.

The MSS is capable of accepting a ± 10% step load change and a ± 5% ramp load change without discharging steam to the condenser or to the atmosphere. For large load change step reductions, steam is bypassed directly to the condenser via the turbine bypass system.

The MSS together with the turbine bypass system is capable of accepting a 100% load rejection without a reactor trip and without lifting MSSVs and MSRVs.

The MSS provides the capacity to dump 67.5% of rated steam flow to the condenser following a 100% load reduction.

The MSS provides the means of dissipating residual and sensible heat generated from the NSSS during hot standby and cooldown conditions, even when the main condenser is not available. Use of the MSDVs or MSRVs allows the controlled cooldown of the steam generators and the reactor coolant system when the condenser is not available.

7.3.2 System Description

The MSS is a steam transport system consisting of piping, valves, and associated instrumentation, and designed to supply steam from the SG outlets to the main turbine. MSS piping and components are located within the containment, in the main steam/feedwater piping area in the reactor building, and in the turbine building. The MSS piping and instrumentation diagrams are shown in Figure 7-2. Table 7-3 provides MSS performance data. The system includes the following major components:

- Main steam piping from the SG outlet steam nozzles to the main turbine stop valves,
- An MSIV and MSBIV in each main steam line,
- A main steam check valve (MSCV) in each main steam line,
- Six MSSVs and an MSRV and MSDV in each main steam line,
- A main steam relief valve block valve (MSRVBV) in each main steam line,
- A branch line from each main steam line to an EFW pump turbine, and
- TBVs.

7.3.3 Component Descriptions

7.3.3.1 Main Steam Piping

The main steam piping is designed such that the pressure drop from the SGs to the turbine main steam stop valves does not exceed 41.3 psi at rated steam flow conditions. The low pressure drop assures that the steam moisture content does not exceed 0.5%. The piping is sized for rated power steam flow conditions. The main steam lines from the SGs are 32 in. in diameter. The main steam lines are connected to the 42-in. equalization piping located near, but below, the high pressure turbine. A portion of the steam from the equalization piping flows to the gland seals, moisture separator reheaters, and deaerator, with the high pressure turbine receiving the balance of the flow via four individual lines and four sets of main turbine stop and control valves. Each of the main steam lines is anchored in the main steam/feedwater piping area adjacent to the turbine building.

The sizing and layout of the main steam piping from the individual SGs hydraulically balance the pressures such that the differential pressure between any two SGs does not exceed 10 psi.

Main steam pipes branching from the equalization piping supply reheating steam to the MSR second-stage tube bundles. Control valves in the reheating steam supply lines control the steam flow to the tube bundles during plant startup and shutdown. Power-operated isolation valves and bypass valves are also located in the MSR reheating steam supply lines.

Branch connections are provided from the main steam lines to supply steam for various functions. Upstream of the MSIVs, connections are provided for the steam supplies to the EFW pump turbines, MSSVs, MSRVs, MSDVs, low point drains, high point vents, and nitrogen blanketing. Branch piping downstream of the MSIVs includes connections for the MSRs, gland seal system (GSS), pegging steam for the deaerator, ASSS, turbine bypass system, and low point drains.

All four main steam lines are tapped to supply the two emergency feedwater pump turbines. This assures a steam supply during a postulated main steam line break accident.

The turbine glands receive sealing steam from the MSS via a branch line from the equalization piping. The branch line connects to the supply header from the ASSS. During startup the ASSS supplies steam to the turbine glands. Sealing steam is switched from the ASSS to the MSS after steam becomes available in the equalization piping. A power-operated valve isolates the MSS from the GSS and ASSS when main steam is not the source for the gland sealing steam.

7.3.3.2 Main Steam Safety Valves

MSSVs with sufficient rated capacity are provided to prevent the steam pressure from exceeding 110% of the MSS design pressure. The total required capacity of these valves is 105% of the main steam flow rate at rated power conditions. The MSSV rated capacities and other specifications are tabulated in Table 7-4.

Six MSSVs are provided per main steam line. The MSSVs are located in the safety-related portion of the main steam piping upstream of the MSIVs and outside the containment in the main steam/feedwater piping area. Adequate space is provided for the installation and support of the valves. Static and dynamic loads during normal operation and during seismic events are considered.

Each MSSV is connected to a vent stack. The stacks are arranged and designed to prevent steam backflow from the transition pieces and to minimize the backpressures on the valve outlets. The vent stacks are designed and supported to withstand SSE loads. The vent stacks are arranged to direct the steam flow away from the adjoining structures, to ensure that no backflow of steam occurs, and to minimize backpressures on the valve outlets to prevent jeopardizing valve rated capacity.

7.3.3.3 Main Steam Relief Valves

One air-operated MSRV is installed on the MSS piping from each SG. The MSRVs' primary function is to prevent an unnecessary lifting of the MSSVs. An MSRV automatically opens, modulates, and exhausts to the atmosphere whenever the associated steam line pressure exceeds a predetermined setpoint. Each valve is designed to trip open within three seconds. As the pressure decreases, the MSRVs modulate to close.

No credit is taken for the MSRVs in support of a safe shutdown.

The valve design data is provided in Table 7-4. The maximum capacity of each valve is limited to reduce the temperature magnitude of a reactor transient, should one valve inadvertently open and remain open.

7.3.3.4 Main Steam Depressurization Valves

One motor-operated MSDV is installed on the main steam piping from each SG. The MSDVs provide for the controlled removal of reactor decay heat (in conjunction with the emergency feedwater system [EFWS]) during the safe shutdown of the plant after a plant transient, accident condition, or emergency condition when the turbine bypass system is not available. The valve opening is regulated from the main control room to cool down the RCS within six hours after the plant has been in hot standby for eight hours. Although they perform a safety function for a plant safe shutdown, the MSDVs are not used for a normal plant shutdown.

The valve design data is provided in Table 7-4. The maximum capacity of each valve is limited to reduce the magnitude of a transient, should one valve inadvertently open and remain open.

All MSRVs and MSDVs are located outside the containment in the main steam/feedwater piping area upstream of the MSIVs in the safety-related portion of the main steam lines. The MSRVs and MSDVs are designed as safety-related ASME Code, Section III, Safety Class 2, Seismic Category I.

7.3.3.5 Main Steam Relief Valve Block Valves

An MSRVBV with remote control is located upstream of each MSRV and MSDV pair to facilitate isolation of a leaking or stuck-open MSRV or MSDV. The MSRVBVs are closed manually from the main control room. They automatically close when steam line pressure reaches a predetermined setpoint.

7.3.3.6 Main Steam Isolation and Check Valves

The function of the MSIVs is to limit the uncontrolled steam release from the MSSS so that no more than one SG blows down in the event of a main steam line break (MSLB) with a single active failure. Limiting the steam release during an MSLB:

- Limits the effect on the reactor core to within the specified fuel design limits, and
- Limits containment pressure to a value less than the design pressure.

If the MSLB occurs upstream of the MSIVs, the faulted SG is isolated from the others by the MSIVs in the main steam piping of the intact SGs or by the MSIV/MSCV of the broken line. In the case of a line break downstream of the MSIVs, the MSIVs in the main steam piping of both the intact SGs and the faulted SG would prevent steam blowdown from more than one SG.

Each MSIV is a medium-actuated gate valve which uses the valve's internal pressure for closing. These valves are located outside the containment in the main steam/feedwater piping area. The MSIVs are designed to fully close within five seconds after the receipt of one of the following signals:

- Low main steam line pressure,
- High-high containment pressure,
- High main steam line pressure negative rate, or
- Manual actuation.

Valve design parameters are provided in Table 7-4.

7.3.3.7 Main Steam Bypass Isolation Valves

Each MSBIV is installed in parallel with an MSIV. The MSBIVs are used to warm up the main steam lines prior to a plant startup when the MSIVs are closed. The valves also equalize the pressure on either side of the MSIVs to enable opening of the MSIVs. The bypass valves are air-operated globe valves that are closed during normal plant operation. The valves are designed to close within five seconds automatically in response to the same signals which automatically close the MSIVs.

Valve design parameters are provided in Table 7-4.

7.3.3.8 Turbine Bypass Valves

The turbine bypass system (TBS) originates in the turbine bypass valve header tapped from the main steam equalization piping upstream of the main turbine stop valves. Two individual subheaders per condenser shell are tapped from the bypass valve header. The lines containing the TBVs are connected to these subheaders. The TBVs discharge to the condenser shells via two subheaders per shell.

A total of 15 10-in. TBVs are provided. Each of three sets of five valves discharges to a separate condenser shell. The TBVs are air-operated globe valves with positioners. The valves are designed to fully open in 3 seconds after the receipt of the signal and then to modulate proportionally within 20 seconds. The valves fail closed on the loss of air or electrical signal. Each valve's modulating positioner responds to the signal from the control system and provides the appropriate air pressure to the valve actuator to modulate the valve position. The reactor control system controls the valve operation.

The TBS has two operating modes:

- T_{avg} control mode, and
- Pressure control mode.

The T_{avg} control mode is the standby mode for at-power transients requiring turbine bypass, such as load rejections (for which the load rejection controller responds) and turbine trips (for which the turbine trip controller responds). In this mode, the turbine bypass system operates to sustain a 100% load rejection without generating a reactor trip or actuating an MSRV, MSSV, or pressurizer safety valve. The TBVs also remove stored energy and residual heat following a reactor trip.

The load rejection sensing circuit unblocks the TBVs when the rate of load rejection exceeds a 10% step load decrease or a sustained ramp load decrease of greater than 5% per minute. For power changes less than or equal to a 10% change in the electrical load or less than or equal to 5% per minute ramp load change, the TBVs are not actuated. The load rejection controller prevents a large increase in the reactor coolant temperature following a large, sudden load decrease. The error signals for the controller are the difference between the lead-lag compensated selected T_{avg} and the selected T_{ref} based on turbine inlet pressure, and the difference between the nuclear power signal and the turbine inlet pressure with a rate-lag compensation.

Following a turbine trip, the load rejection controller is defeated and the turbine trip controller becomes active. The error signal for the controller is the difference between the lead-lag compensated T_{avg} and the no-load reference T_{avg}.

The pressure control mode is the no-load operational mode. Pressure mode control is used to remove decay heat during plant startups and cooldowns. The difference between the steam equalization piping pressure and a pressure setpoint serves as the error signal for controlling the turbine bypass flow. The pressure setpoint is manually adjustable and is based on the desired reactor system coolant temperature.

7.3.4 System Operation

7.3.4.1 Normal Operation

During startup, the main steam piping is heated by opening the MSBIVs and controlling the steam flow. Main steam is not admitted to the main turbine until the warmup of the main steam piping is accomplished. After the warmup, the secondary-side no-load temperature and pressure are maintained automatically by the turbine bypass system operating in the pressure control mode. When the reactor coolant temperature reaches 557°F (the no-load temperature), the MSIVs are opened in a controlled manner. As the piping downstream of the MSIVs is heated, the MSIVs are opened fully and the MSBIVs are closed.

The MSR second-stage steam supplies remain closed below 10% turbine load. With turbine load greater than 10%, heating steam is admitted by opening the warmup valves to the tube bundles.

During hot standby operation, the SG pressure is controlled by modulating the TBVs as they dump steam to the condenser.

During a plant cooldown, decay and sensible heats are removed by dumping steam to the condenser via the TBVs. When the steam pressure falls below 125 psia, steam dump operation is stopped, and the cooldown is switched to residual heat removal system operation.

7.3.4.2 Emergency Operation

In the event that the plant must be shut down due to an accident or transient, the MSIVs and their associated MSBIVs are closed. The MSDVs are operated to remove the reactor decay heat and primary system sensible heat in order to cool down the primary system to the conditions at which the residual heat removal system can perform the remaining cooldown. If one of the MSDVs is unavailable, the safety valves associated with that main steam line provide overpressure protection. The remaining MSDVs have sufficient capacity to cool down the plant.

In the event of a design-basis accident, such as a main steam line break, the MSIVs and their associated MSBIVs are automatically closed. Even if a single failure is assumed, the closure of the MSIVs and the MSBIVs, or the seating of an MSCV associated with a faulted SG, ensures that no more than one SG blows down.

7.4 Condensate and Feedwater System

The condensate and feedwater system (CFS), depicted in Figure 7-3, provides feedwater at the required temperature, pressure, and flow rate to the steam generators. The condensate system delivers water from the condenser hotwell outlets to the deaerator; and the feedwater system delivers water from the outlets of the deaerator to the SG inlet nozzles. Condensate is pumped from the main condenser hotwell by the condensate pumps through the condensate polishing system, the gland steam condenser, and the low pressure feedwater heaters to the deaerator. The feedwater booster/main feedwater pumps take suction from the deaerator and then discharge feedwater through the high pressure feedwater heaters to the SGs.

The CFS provides condensate cleanup capability and maintains condensate quality through dearation and interfacing with the main condenser, condensate polishing system, secondary-side chemical injection system, and secondary sampling system.

7.4.1 Design Bases

7.4.1.1 Safety-Related Design Bases

The safety-related portion of the system is required to function following a design-basis accident to provide containment and feedwater isolation, as discussed below, for the main lines routed into containment.

The portion of the CFS from the SG inlets outward through the containment up to and including the main feedwater isolation valves (MFIVs) is constructed in accordance with the requirements of ASME Code, Section III, Class 2 components and is designed to Seismic Category I requirements. The piping upstream of the

MFIVs to the first piping restraint in each line at the interface between the reactor building (main steam/feedwater piping area) and turbine building is constructed in accordance with the requirements of ASME Code, Section III, Class 3 components and is designed to Seismic Category I requirements.

The safety-related portions of the CFS are designed to remain functional during and after a safe-shutdown earthquake (SSE) and to perform their intended function of isolating feedwater flow following postulated events.

The CFS's intended safety functions can be performed, assuming a single active component failure coincident with the loss of offsite power.

For a feedwater line break (FLB) or main steam line break, the CFS is designed to limit high energy fluid from the break.

For an FLB upstream of an MFIV, the CFS is designed to prevent the blowdown of any SG and also to maintain the availability of emergency feedwater system flows to the SGs.

The main feedwater check valves (MFCVs), each located between the MFIV and the main feedwater regulation valve (MFRV) in the main feedwater line to an SG, act on reverse pressure differential. The MFCVs are designed to withstand the forces encountered when closing after an FLB. The valves serve to prevent the blowdown from more than one SG during a feedwater line break. During upset or abnormal conditions, the function of these check valves is to prevent reverse flow from the SGs whenever the CFS is not in operation.

Main feedwater isolation is provided via the MFIVs. Each of these valves is operated by redundant solenoid valves, which are powered from separate, independent class 1E power buses. The failure of one solenoid valve does not impair the isolation function of an MFIV. The MFIVs are designed to close automatically on main feedwater isolation signals within 5 seconds.

7.4.1.2 Power Generation Design Bases

The CFS is designed with the capability of automatically providing the required flows to the SGs during startups and shutdowns, at power levels up to the rated load, and during the plant design transients without interruption of operation or damage to equipment. Feedwater of uniform temperature is delivered to all SGs at any given power level. A continuous, steady feedwater flow is maintained at all loads.

The system is able to accommodate ± 10% step and ± 5%/min ramp load changes without significant deviation from programmed water levels in the SGs or major effects on the feedwater system. The system has the capability of accommodating the necessary changes in feedwater flow to the SGs with the steam pressure increase resulting from a 100% load rejection.

The plant is designed to operate at rated power with one condensate pump or feedwater booster/main feedwater pump assembly out of service. With one feedwater heater string out of service, the plant is designed for operation at 70% of rated power.

7.4.2 System Description

The CFS supplies the SGs with heated feedwater within the closed secondary cycle using regenerative feedwater heating. The CFS is composed of the condensate system and the feedwater system.

The condensate system takes suction from the main condenser hotwell and pumps condensate forward to the deaerator utilizing condensate pumps. The feedwater system takes suction from the deaerator and pumps feedwater forward to the SGs utilizing the feedwater booster/main feedwater pumps. The feedwater system contains the safety-related piping and valves that deliver feedwater to the SGs. The condensate system and part of the feedwater system are located within the turbine building; the safety-related portion of the feedwater system is located within the reactor building and inside the containment.

The condensate flow originates from the main condenser, pumped from the main condenser hotwell by the condensate pumps. The main condenser hotwell receives makeup from the condensate storage tank. Most of the condensate passes, in sequence, through the condensate polishers or condensate polisher bypass line; the gland steam condenser; and three strings of low pressure feedwater heaters, each string consisting of four low pressure feedwater heaters. The condensate is delivered to the deaerator. Heater drainage from the fourth- and third-stage low pressure feedwater heaters are cascaded to the second-stage heaters. Drains from the first- and second-stage heaters are collected in the heater drain tanks and then pumped forward by the low pressure heater drain pumps to the main condensate lines between the first- and second-stage heaters. A portion of the condensate flow downstream of the condensate polishers is diverted to provide cooling to the SG blowdown system regenerative heat exchangers before returning to the main condensate flow at the deaerator.

The condensate system consists of the main condenser, condensate polishing system, condensate pumps, four stages of low pressure heaters, the deaerating feedwater heater (deaerator), piping, and associated valves and instrumentation.

Four 33%-capacity parallel feedwater booster/main feedwater pumps take suction from the deaerator and deliver feedwater through two strings of high pressure heaters to the four SGs. The inlet piping to each SG contains a flow element, an MFRV, a main feedwater bypass regulating valve (MFBRV), an MFIV, and an MFCV.

Condensed heating steam from the MSRs is collected and cascaded via the seventh- and sixth-stage high pressure feedwater heaters into the deaerator. MSR shell drains are collected and pumped to the deaerator. These drains are thus pumped forward in the feedwater system.

During plant startup, recirculation paths facilitate system cleanup and adjustment of water quality prior to initiating feed to the SGs. Steam is provided to the deaerating feedwater heater from the auxiliary steam supply system to preheat the feedwater to over 230°F during the initial cleanup and startup recirculation operations. This preheating action, along with chemical addition, minimizes the formation of iron oxides in the CFS.

The condensate system interacts with the condensate storage tank to maintain the required plant secondary-cycle inventory. The secondary-side chemical injection system injects both an oxygen scavenging agent and a pH control agent into the condensate piping downstream of the condensate polishers and into the feedwater piping downstream of the main feedwater pumps.

During rated-power operation, two of the three 50%-capacity condensate pumps are operating; the third pump is in standby and available for an automatic start. All feedwater booster/main feedwater pumps are operating during rated-power operation. Each pump is designed to deliver 25% of rated feedwater flow during rated operation. With an increase in pump speed, each pump is also capable of delivering 33% of rated feedwater flow at rated operating pressure.

When feedwater flow demands are low, the feedwater booster/main feedwater pumps provide feedwater form the deaerator via the smaller diameter water filling line. This line emanates from the feedwater pump common discharge piping and then branches into four lines, one for each SG. Each filling line joins its associated main feedwater line downstream of the MFBRV. Each SG water filling line has a steam generator water filling control valve (SGWFCV).

7.4.3 Component Descriptions

Design parameters for the major feedwater valves are listed in Table 7-5. Design parameters for the major system components are listed in Table 7-6.

7.4.3.1 Main Feedwater Isolation Valves

The MFIVs are Seismic Category I, ASME Code, Section III, Class 2 valves. One MFIV is installed in each of the four 16-in. main feedwater lines outside containment and downstream of the MFCV. The MFIVs provide the safety-related functions of main feedwater isolation and containment isolation.

Each MFIV is a medium-actuated gate valve which uses the valve’s internal pressure for closing. Each MFIV is operated by redundant solenoid valves powered from separate Class 1E power buses.

The MFIVs are designed to be capable of tripping closed within 5 seconds after receiving an isolation signal in response to an ECCS actuation signal or high-high SG water level in any one of the SGs.

7.4.3.2 Main Feedwater Regulation Valves

The MFRVs are air-operated, 16-in. globe valves with the purpose of controlling the feedwater flow rates. The MFRVs are designed to ASME Code, Section III, Class 3, and are Seismic Category I. Each MFRV automatically maintains the water level in the associated SG during operational modes. Positioning of the MFRV during normal operation is the function of an automatic SG water level control system using a conventional three-element control scheme (feedwater flow, steam flow, SG water level).

The MFRVs are designed to close within 5 seconds after receiving an isolation signal in response to an ECCS actuation signal, high SG water level, high-high SG water level, or permissive P-4 and low T_{avg} signal.

7.4.3.3 Main Feedwater Check Valves

Each main feedwater line includes an 18-in. MFCV installed outside containment. The valves are designed to ASME Code, Section III, Class 3, and are Seismic Category I. During normal and upset conditions, each MFCV prevents reverse flow from the associated SG whenever the feedwater pumps are tripped. In addition, the closure of the valves prevents more than one SG from blowing down in the event of a feedwater line break. Each MFCV is designed to limit blowdown from the associated SG and to prevent water hammer due to sudden valve closure.

7.4.3.4 Main Feedwater Bypass Regulation Valves

The 6-in. MFBRVs are designed to ASME Code, Section III, Class 3, and are Seismic Category I. The MFBRVs are installed to bypass the MFRVs and to control main feedwater flows from approximately 3% to 15% of rated power. Each MFBRV's position is controlled with a three-element (feedwater flow, ΔT, SG water level) control system.

The MFBRVs are designed to close within 5 seconds after receiving an isolation signal in response to an ECCS actuation signal, high SG water level, or high-high SG water level.

7.4.3.5 Steam Generator Water Filling Control Valves

Each SGWFCV is positioned from no load up to 3% of rated power by a one-element (SG water level only) controller.

The SGWFCVs are designed to close within 5 seconds after receiving an isolation signal in response to an ECCS actuation signal or high-high SG water level.

7.4.3.6 Main Condenser

The main condenser functions to condense and deaerate the exhaust steam from the main turbine and to provide a heat sink for the turbine bypass system.

The main condenser is a three-shell, single-pass, single-pressure, and rigidly supported unit with divided water boxes. Each shell is located beneath its respective low pressure turbine element. The condenser is equipped with titanium tubes. The titanium material provides good corrosion- and erosion-resisting properties.

The condenser shells operate at the same pressure and temperature due to the equalizing pipes which connect the condenser shells at the neck area. Condensate is drawn from the hotwell of each condenser section and then combined in a common header to the suction of the condensate pumps.

The condenser shells are located below the turbine building operating floor and are rigidly supported on the turbine foundation. An expansion connection is provided between each low pressure turbine exhaust opening and the associated steam inlet connection of the condenser. Four low pressure feedwater heaters are located in the neck area of each condenser shell.

Air inleakage and noncondensable gases contained in the turbine exhaust steam are collected in the condenser and removed by the vacuum pumps of the main condenser evacuation system. The noncondensable gases exhausted by the vacuum pumps are directed to the vent of the evacuation system and monitored for radioactivity prior to discharge to the environment.

7.4.3.7 Condensate Pumps

Three 50%-capacity, vertical, multistage, centrifugal, motor-driven condensate pumps operate in parallel. The valve arrangement allows an individual pump to be removed from service. The pump capacities meet the rated power requirements with two of the three pumps in operation.

7.4.3.8 Condensate Regulating Valves

The main condensate flow to the deaerator is regulated by two parallel, split-ranged, pneumatically operated control valves. Condensate flow is regulated to maintain the level in the deaerator storage tank. During startup and low loads, the smaller valve modulates to control flow while the larger valve remains closed. As the load increases, the larger valve modulates to control flow.

7.4.3.9 Low Pressure Feedwater Heaters

The low pressure feedwater heaters are shell-and-tube heat exchangers with the heated condensate flowing through the tube sides and the extraction steam condensing on the shell sides. The heater shells are carbon steel, and the tubes are stainless steel. A parallel string of first-, second-, third-, and fouth-stage feedwater heaters is located in each of the three main condenser necks. Each low pressure feedwater heater has an integral drain cooler. The fourth- and third-stage heater shell-side drains cascade to the next lower stage feedwater heater. The drainage from each second- and first-stage heater flows to its respective low pressure feedwater heater drain tank. A drain line from each low pressure feedwater heater allows direct discharge of the heater drainage to the main condenser in the event that the normal drainage path is not available or if flooding occurs in the heater.

7.4.3.10 Deaerator

The deaerator is a spray-tray-type, horizontal-shell, direct-contact heater located on top of a horizontal storage tank. The internal components of the deaerator include a tray stack and spray valves. Condensate enters the deaerator from the top and is sprayed by the spray valves into a spray chamber. Heating steam flows from the bottom up through the trays and into the spray chamber. As the heating steam is condensed, it raises the temperature of the condensate to near saturation, thereby liberating dissolved gases from the condensate. The condensate then cascades through the tray section, exposing a large surface area of condensate to the scrubbing action of the countercurrent rising steam. The heated condensate drains from the deaerator through downcomers into the storage tank. Noncondensable gases are vented from the top of the deaerator and directed through an orifice-and-valve assembly to the main condenser.

During a plant startup, auxiliary steam from the auxiliary steam supply system is supplied to the deaerator during recirculation conditions and maintains the pressure in the tank above atmospheric. The steam heats the condensate during cleanup and recirculation for liberation of noncondensable gases. Auxiliary steam is also automatically supplied to the deaerator following a turbine trip to assist in maintaining deaerator pressure above atmospheric.

The shells of the deaerator and the deaerator storage tank are carbon steel. Most of the internals of the deaerator, including the tray assemblies and spray valves, are stainless steel. A high level dump line with a control valve provides overflow protection for the deaerator storage tank. Water from the deaerator storage tank is drained to the main condenser during high level conditions.

7.4.3.11 High Pressure Feedwater Heaters

The main feedwater pumps discharge to the SGs via two parallel strings of sixth- and seventh-stage high pressure feedwater heaters. These heaters are shell-and-tube heat exchangers with integral drain coolers. The heater shells are carbon steel, and the tubes are stainless steel. Heated feedwater flows through the tubes, and extraction steam condenses in the shells. Each seventh-stage feedwater heater shell drains to the associated sixth-stage heater, and each sixth-stage feedwater heater shell drains to the deaerator. A drain line from each heater allows direct discharge of the heater drainage to the main condenser in the event the normal drain path is not available or if flooding occurs in the heater.

7.4.3.12 Feedwater Booster/Main Feedwater Pumps

The four 33%-capacity feedwater booster pumps are horizontal, centrifugal pumps with identical characteristics, located upstream of the main feedwater pumps. Each feedwater booster pump takes suction from the deaerator storage tank and pumps forward to its associated main feedwater pump. An electric motor drives both the booster pump and the main feedwater pump. The feedwater booster pump is driven by one end of the motor shaft, and the main feedwater pump is driven by the other end through a hydraulic coupling. The feedwater booster pump, operating at a lower speed than the main feedwater pump, boosts the pressure of the feedwater from the deaerator to meet the net positive suction head requirements of the main feedwater pump.

Four 33%-capacity main feedwater pumps operate in parallel and take suction from the associated feedwater booster pumps. The combined discharge from the main feedwater pumps is supplied to the high pressure feedwater heaters and then to the SGs. The main feedwater pumps are horizontal, centrifugal pumps with identical characteristics. Each is driven through a hydraulic coupling by the motor that drives the associated feedwater booster pump.

Isolation valves allow each pair of feedwater booster and main feedwater pumps to be individually removed from service while power operations continue at a reduced capacity.

7.4.3.13 Low Pressure Feedwater Heater Drain Pumps and Tanks

The three 33%-capacity low pressure heater drain pumps are vertical, turbine-driven, multistage pumps. Each pump takes suction from its associated low pressure feedwater heater drain tank and pumps the collected drains to the associated condensate string between the first- and second-stage low pressure feedwater heaters.

The three 33%-capacity low pressure feedwater heater drain tanks are horizontal, cylindrical tanks with sufficient storage margins to accommodate system transients.

7.4.3.14 Pump Recirculation Systems

Minimum flow control systems automatically protect the pumps in the CFS from pumping below the minimum necessary flow rates to prevent pump damage. The condensate pumps recirculate to the main condenser. The feedwater booster/main feedwater pumps recirculate to the deaerator storage tank, and each low pressure feedwater heater drain pump recirculates to its associated low pressure feedwater heater drain tank.

7.4.4 System Operation

7.4.4.1 Plant Startup

Three recirculation loops are provided to allow for system cleanup and adjustment of water chemistry during plant startups prior to initiating feed to the SGs. These loops are:

Hotwell Recirculation Loop: This loop facilitates cleanup of the condensate inventory in the main condenser hotwell by the condensate polishing system. This loop recirculates condensate through the polishers, returning flow to the condenser from a point downstream of the gland steam condenser. With a condensate pump operating, hotwell recirculation is started by adjusting the recirculation flow control valve to the required flow rate and placing the polishers in service to achieve the required water quality. This loop also provides a minimum flow for operation of the gland steam condenser and the condensate pumps.

Deaerator Recirculation Loop: This loop facilitates cleanup of the condensate system. Recirculated condensate flows through the condensate polishers, returning to the condenser from a point downstream of the deaerator. Deaerator recirculation is started by adjusting the recirculation flow control valve to the required flow with the condensate polishers in operation. Auxiliary steam can be admitted to the deaerator to heat the condensate for the liberation of noncondensable gases. This loop also serves as a high level dump path to provide overflow protection for the deaerator storage tank.

Long-Cycle Recirculation Loop: Long-cycle recirculation can begin when the condensate and feedwater has been sufficiently cleaned and deaerated up to the feedwater booster/main feedwater pump suctions. Flow is initiated by adjusting the recirculation flow control valve to achieve the required flow rate. Feedwater is recirculated from each main feedwater line at a point upstream of the MFIV to the main condenser for cleanup and deaeration of the condensate and feedwater inventory.

7.4.4.2 Plant Heatup

The condenser hotwell makeup and overflow valves are enabled and function automatically during the plant heatup evolution to maintain condensate inventory. Condensate is returned to the condensate storage tank as volume expansion occurs, and makeup occurs as needed for system losses. During heatup, the main condenser is available to accept turbine bypass steam, as well as various drains and vents and condensate/feedwater recirculation flow. Noncondensable gases are removed in the air removal sections of the main condenser and through the deaerator vents. Control and monitoring of water quality and chemistry are accomplished through operation of the condensate polishing system, secondary-side chemical injection system, and secondary sampling system as required.

The SGs are filled by a feedwater booster/main feedwater pump taking suction from the deaerator storage tank, and supplied via the SG water filling lines and the SGWFCVs. The SGs are drained, as required, through the steam generator blowdown system.

During the initial stages of a plant heatup, one condensate pump operates as necessary to maintain the level in the deaerator storage tank. One feedwater booster/main feedwater pump is in operation when feeding water to the SGs. The feedwater pumps in use operate on minimum flow recirculation, as necessary, while maintaining the water level of the SGs. Feedwater is controlled by the SGWFCVs, which are operated either manually from the control room or automatically by one-element control in accordance with the SG water level demand. Condensate flow to the SG blowdown heat exchangers is controlled during plant heatup to obtain the necessary cooling of the blowdown stream. Any excess level in the deaerator storage tank is automatically drained to the main condenser through the deaerator high level dump.

The amount of feedwater added to the SGs as the reactor coolant is heated from cold shutdown conditions to the no-load RCS temperature of 557°F is not large because the secondary water volume increases gradually due to thermal expansion, and steam consumption is small in the pertinent period.

7.4.4.3 Normal At-Power Operation

One operating condensate pump supplies sufficient condensate flow to the deaerator during initial power operation and at low power levels. As the power level increases, a second condensate pump is started before the approximately 50% capacity of the first condensate pump is exceeded. The third condensate pump is in standby.

The condensate regulating valves automatically maintain the level in the deaerator storage tank. If condensate flow to the deaerator drops below the minimum required flow for operation of the gland steam condenser or the condensate pumps, the hotwell recirculation valve opens to provide the minimum flow.

Noncondensable gases are removed by the deaerating section of the main condenser and by the deaerator. The condensate polishing system, secondary-side chemical injection system, and secondary sampling system are operated as needed to maintain water quality.

For normal operating conditions between 0 and 100% load, system operation is primarily automatic. Automatic level control systems control the water levels in the feedwater heaters and in the condenser hotwell. Level control valves in the makeup line to the condenser from the condensate storage tank and in the return line to the condensate storage tank control the level in the condenser hotwell.

The system is able to accommodate 10% step or 5% per minute ramp load changes without significant deviation from programmed water levels in the SGs or major effects on the feedwater system. The system also has the capability of accommodating the necessary changes in feedwater flow to the SGs with the steam pressure increase resulting from a 100% load rejection.

7.4.4.4 Plant Shutdown

As power is decreased, the numbers of operating condensate and booster/main feedwater pumps are reduced. At low feedwater flow demands, control of the feedwater is transferred from the MFRVs to the MFBRVs (at about 15% of rated power), and then to the SGWFCVs (at about 3% rated power). Following reactor shutdown, decay heat and sensible heat are removed by steam release via the TBVs to the condenser to cool the plant and bring it to RHR cut-in conditions.

7.4.4.5 Emergency Operation

During a design-basis event, feedwater isolation signals are generated as required. The MFIVs, MFBRVs, MFRVs and SGWFCVs automatically close on receipt of an isolation signal. The CFS is not required to supply feedwater under accident conditions to effect a plant shutdown or to mitigate the consequences of an accident. During an accident the SGs are fed with water by the EFWS; residual heat from the reactor coolant system is removed by steam relief through the main steam depressurization valves.

7.5 Condenser Circulating Water System

The condenser circulating water system (CWS), depicted in Figure 7-4, supplies cooling water to remove heat from the main condenser under varying conditions of power plant operation and site environmental conditions.

7.5.1 Design Bases

The CWS does not have a safety-related function and has no safety design basis.

During normal operation, the CWS removes the condenser heat load during startups, normal shutdowns, and transient conditions, and following turbine trips, when a portion of the main steam is bypassed to the main condenser via the turbine bypass valves. If the main condenser is not available during a loss of offsite power event, the cooldown of the reactor is achieved by using the main steam depressurization valves rather than the turbine bypass system.

7.5.2 System Description

The CWS draws water from the CWS cooling tower basins, and returns the water to the basins after pumping it through the main condenser. The CWS supplies cooling water at the specified flow rate to condense the steam in the condenser. The COL applicant is to determine the site-specific final system configuration and system design parameters for the CWS, including makeup and blowdown details.

The CWS is automatically isolated in the event of gross leakage into the turbine building condenser area to prevent flooding of the turbine building. The CWS is designed such that a failure in a CWS component (piping, cooling tower, expansion joint, pump, etc.) does not have a detrimental effect on any safety-related equipment. Any leakage from the CWS due to tube leakage into the main condenser is detected by the secondary sampling system.

The CWS is composed of eight 12.5%-capacity circulating water pumps, cooling towers, cooling tower basins, makeup water pump(s), blowdown pump(s), and associated piping, valves, strainers, and instrumentation. The circulating water pumps, located in the cooling tower basins, take suction from the basins and pump water through the main condenser under varying conditions of power plant loading and design weather conditions. The two cooling tower assemblies provide 100 percent cooling for normal power operation. Each cooling tower assembly contains two back-to-back rows of cooling towers. The discharge piping from the circulating water pumps is combined into intake manifold concrete pipes, as shown in Figure 7-4. The CWS supply and return piping to and from the three-shell main condenser contains butterfly-type isolation valves.

Makeup water is provided by the raw water system to compensate for cooling tower evaporation, drift, and blowdown. The basin water chemistry is controlled by the CWS/raw water chemical treatment system. A biocide, algaecide, pH adjuster, corrosion inhibitor, and silt dispersant are injected into the CWS by the chemical injection system to maintain a nonscale-forming condition and to limit biological growth.

Two nonessential service water (non-ESW) pumps, located in the turbine building, take suction from the CWS piping in the turbine building. The non-ESW flow cools the turbine component cooling water system (TCS) heat exchangers and then returns to the main condenser outlet piping. The TCS is maintained at a higher pressure than the non-ESW system to prevent leakage from the non-ESW system into the TCS. The cooling towers are sized to handle the heat loads of the condenser and the TCS heat exchangers.

7.5.3 Component Descriptions

The circulating water system consists of the following major components:

- Circulating water pumps,
- Cooling towers and cooling tower basins,
- Main condenser,
- Condenser tube cleaning equipment,
- Cooling tower makeup water and blowdown systems,
- Chemical treatment system, and
- Instrumentation and controls.

Design parameters for the major components are listed in Table 7-7.

7.5.3.1 Circulating Water Pumps

The eight 12.5%-capacity circulating water pumps are vertical, wet-pit-type, single-stage, mixed-flow pumps driven by direct-drive electric motors. Each cooling tower basin contains four circulating water pumps that are arranged in parallel.

7.5.3.2 Cooling Towers

Mechanical draft cooling towers have been selected for the CWS. Each of the two cooling towers has 30 cells, arranged in two rows of 15 cells in each row, with the rows arranged back to back.

The cooling towers are located outdoors at a sufficient distance from any equipment or structure important to reactor safety. The cooling towers and their foundations are designed for wind and earthquake loads.

7.5.3.3 Cooling Tower Makeup Water Pumps

Two 100%-capacity makeup water pumps provide makeup water to the cooling tower basins. The makeup water pumps are vertical, electric-driven pumps located in the raw water intake structure.

7.5.3.4 Cooling Tower Blowdown Pumps

One of two 100%-capacity blowdown pumps is located in each cooling tower basin. Each pump takes suction from a cooling tower basin and discharges into the raw water source.

7.5.4 System Operation

During a plant startup, the CWS is placed in operation before a vacuum is drawn in the main condenser.

During normal at-power operation, the circulating water pumps take suction from the cooling tower basins and circulate water through the tube side of the single-pass main condenser to maintain the required vacuum conditions, and the circulating water is returned to the discharge piping network in the cooling towers. The mechanical draft cooling towers cool the circulating water by discharging the water over networks of baffles in the towers. Some of the water evaporates into the air flowing through the towers; the remaining water falls into the basins beneath the cooling towers. In the process, the heat load from the condenser is rejected to the atmosphere.

The flow to the cooling towers can be diverted directly to the basins, bypassing the tower internals, by opening the motor-operated bypass valve(s).

The makeup water pumps supply water to the cooling tower basins to replace water losses due to evaporation, wind drift, and blowdown. Also, biocides are added as needed to the circulating water to control biological growth. Blowdown water from the CWS is taken from the cooling tower basins, dechlorinated as required, and discharged. Discharge into the lake/river/pond meets appropriate regulatory requirements.

During a plant shutdown when the condenser is available, the CWS operates until the residual heat removal system is placed in service. The CWS is not required for a safe shutdown following a design-basis accident, nor when the condenser is not available.

7.6 Emergency Feedwater System

The emergency feedwater system is designed to supply feedwater to the steam generators whenever the reactor coolant temperature is above 350°F and the feedwater system is not in operation. The EFWS is designed to remove reactor core decay heat and reactor coolant system sensible heat through the SGs following transient conditions or postulated accidents such as a reactor trip, a loss of main feedwater, a main steam line break, a feedwater line break, a loss of offsite power (LOOP), small-break loss-of-coolant accident (LOCA), a station blackout (SBO), an anticipated transient without scram (ATWS), and a steam generator tube rupture (SGTR). The EFWS is not normally used during normal plant startups and cooldowns.

The EFWS consists of two motor-driven pumps, two steam-turbine-driven pumps, two emergency feedwater pits, piping, valves and associated instrumentation. The EFWS is an ASME Code, Section III, Classes 2 and 3, Seismic Category I, redundant-train system with Class 1E electric components. The EFWS design meets the requirements of NUREG-0737 regarding emergency feedwater issues.

The EFWS supplies feedwater to the SGs at sufficient flow rates to meet the requirements for the transient conditions or postulated accidents while maintaining hot standby conditions. Flow rates are controlled as necessary to maintain stable plant conditions by the motor-operated emergency feedwater control valves.

7.6.1 Safety-Related Design Bases

The EFWS is designed to remain functional after a safe-shutdown earthquake (SSE). The essential portions of the EFWS components are designed to Seismic Category I requirements and are located inside the reactor building, which is designed for seismic, wind, and tornado effects. The EFWS components and piping also have sufficient physical separation and shielding to protect against the effects of postulated missiles.

The functional performance of the EFWS is not affected by the environmental conditions, internal flooding, pipe whip, or jet impingement that may result from high or moderate energy piping breaks or cracks. The building in which the EFWS components are located is designed for and provided with suitable flood protection during abnormally high water levels (adequate flood protection considering the probable maximum flood) to ensure functional capability.

A malfunction or single active failure of a system component or nonessential equipment does not reduce the performance capabilities of the EFWS. The EFWS and supporting systems ensure the required flows to the SGs in the event of a single active failure. The EFWS can perform all safety-related functions assuming a single active component failure in one train and a maintenance outage of one active component in another train.

The EFWS can utilize diverse power sources such that the system performance requirements are met with either power source (ac or dc). The EFWS satisfies the requirement that the pumps be powered by diverse power sources.

The EFWS is designed to provide emergency feedwater automatically for the removal of sensible heat and reactor core decay heat so that there is no damage to the reactor core following a loss of main feedwater, in order to bring the reactor coolant from operating temperatures to the point at which the residual heat removal system (RHRS) may be placed in operation. In the SGs the emergency feedwater is converted to steam, which is then discharged to the atmosphere. The EFWS is automatically initiated by one or more of the EFW actuation signals, which include the LOOP signal, the ECCS actuation signal, the main-feedwater-pumps-trip (all pumps) signal, or a low steam generator water level in any of the SGs. The automatic initiating circuits are powered from the emergency buses.

The EFWS design provides the capability to automatically terminate EFW flow to a depressurized (faulty) SG and to automatically provide EFW to the intact SGs. The EFWS design is also capable of automatically terminating EFW flow to prevent overfilling of SGs.

The EFWS is designed such that in the unlikely event that the main control room (MCR) must be evacuated, the EFWS can be operated from the remote shutdown console.

The EFWS design meets the provisions of the TMI Action Plan of NUREG-0737 regarding the automatic and manual initiation of the system, and of 10 CFR 50.62(c)(1) regarding the automatic initiation of the system on conditions indicative of an ATWS.

The EFWS has the capability for operation at hot standby for eight hours followed by six hours of cooldown to the RHR cut-in temperature, with control from the MCR using only safety-related equipment, and with a single active failure. The EFWS is designed with two EFW pits; both pits together provide a volume of water sufficient for the emergency condition.

The EFWS is designed with sufficient diversity to remain operable for a limited duration with neither offsite nor onsite ac power available. Turbine-driven pumps are designed to be available for the SBO condition.

The EFWS is designed and constructed in accordance with ASME Code, Section III, Class 3 requirements up to the motor-operated EFW isolation valves (containment isolation valves). The containment isolation valves and the downstream piping to the feedwater system are safety class 2.

The EFW pump turbine steam supply isolation valves (containment isolation valves) and the steam piping upstream of the containment isolation valves are designed and constructed in accordance with ASME Code, Section III, Class 2 requirements. The steam supply lines to the EFW pump turbines downstream of the containment isolation valves are designed and constructed in accordance with ASME Code, Section III, Class 3 requirements.

7.6.2 System Description

The EFWS flow diagram is shown in Figure 7-5. The system consists of two motor-driven pumps, two steam-turbine-driven pumps, two EFW pits, and associated piping, valves, instruments and controls. The EFWS components are located in the reactor building. Table 7-8 provides design data for the major components in the EFWS.

The EFWS is comprised of four 50%-capacity pumps. Each EFW pump is sized to supply the feedwater flow required for removal of 50% of the decay heat from the reactor. The EFWS capacity is sufficient to remove decay heat and to provide adequate feedwater for cooldown of the RCS at an approximate average rate of 50°F/hr. Main steam depressurization valves are used to relieve the steam produced in the EFW-supplied SGs during a safe shutdown, following transient and accident conditions.

For a transient or accident condition, the EFW flow is delivered within 140 seconds of any automatic EFW actuation signal to at least two effective (intact) SGs.

The EFWS is designed with two 50% EFW pits, with both pits together providing a sufficient volume of water required for the emergency condition.

The EFW pumps take suction from the two EFW pits. The design of the EFW pits provides heat removal capability for a period of 14 hours. This period consists of 8 hours at hot standby, followed by a 6-hour cooldown of the primary system at an average rate of approximately 50°F/hr.

Each EFW pump discharge line connects with a tie line via a motor-operated isolation valve. During normal plant operation (with no on-line maintenance in progress), all discharge tie-line isolation valves are in the closed position to provide separation of the four trains. With on-line maintenance of one of the trains in progress, the tie-line isolation valves are required to be open, so that the specified flow rate of EFW is available to the SGs, assuming maintenance on one EFW pump and a failure of one of the three remaining EFW pumps.

The motor-operated EFW isolation and control valves provided in the EFW pump discharge lines operate automatically to terminate flow to an affected SG and to continuously supply feedwater to intact SGs as discussed below:

- **Main Feedwater Line Break:** In the event of an FLB, the EFW line connected to that SG is automatically isolated by redundant motor-operated valves, which close in response to a low steam pressure signal. As a result, almost none of the EFW pump flow is lost by spilling out of the break. The logic is such that only one EFW line can be automatically isolated.

- **Main Steam Line Break:** In the event of an MSLB, the SGs depressurize and the EFWS provides SG feedwater flow. In order to prevent excessive SG feedwater flow and pump runout, the motor-operated EFW control valve located in the EFW discharge line to each SG is provided with a preset open position. This position is adjusted and set during preoperational testing. The line to the faulted SG is isolated automatically, as discussed above for the rupture of a main feedwater line; the termination of flow to the faulted SG limits the RCS cooldown and mass/energy release to the containment.

- **Steam Generator Tube Rupture:** Upon detection of a water level increase in an SG, the EFW isolation and control valves for that SG are automatically closed.

7.6.3 Component Descriptions

7.6.3.1 Emergency Feedwater Pumps

Each EFW pump is normally aligned to feed one SG. Each EFW pump takes suction from one of the two EFW pits and discharges to one of the four SGs.

Each EFW pump is designed to develop a head adequate to supply the design flow of at least 400 gpm to an SG, when the SG pressure is equivalent to the set pressure of the lowest set main steam safety valve plus 3% of accumulation, and when the pump discharge tie line is closed.

The maximum EFW pump flow is limited by the motor-operated EFW control valves, which have preset open positions.

A minimum-flow line from each EFW pump's discharge line to an EFW pit, with a normally open valve and an orifice, is provided to maintain the minimum flow required for pump protection. The minimum-flow line ensures a minimum recirculation flow for pump cooling whenever the associated pump is running. The minimum-flow lines from the A and B EFW pumps combine into a common return line to the A EFW pit, and the minimum-flow lines from the C and D EFW pumps combine into a common return line to the B EFW pit. In accordance with NRC IE Bulletin IEB 88-04, each minimum-flow line is designed with sufficient capacity that neither of the pumps which share minimum-flow lines becomes dead-headed. For each pump, a separate, parallel full-flow line, with a normally closed valve and an orifice, allows pump testing during normal plant operation at the pump design flow rate without injection to the SGs. Both the minimum-flow line and full-flow line are routed to the EFW pit by a common header.

Two motor-driven and two turbine-driven EFW pumps, with separate power supplies, are provided. The two motor-driven EFW pumps are connected to different safety ac buses so that specific safety functions are achieved in the event of off-site power loss; each bus is backed by a redundant emergency power source. The motor-driven EFW pumps are horizontal, centrifugal pumps. Each motor-driven pump has a capacity of 450 gpm. The capacity of each pump is based on the required flow of 400 gpm to an SG and 50 gpm through the minimum-flow line.

The turbine-driven EFW pumps provide diversity of motive pumping power. Each pump is a horizontal, centrifugal unit with a capacity of 550 gpm. The capacity is based on the required flow of 400 gpm to an SG and 150 gpm through the minimum-flow line.

The steam supply line to each turbine-driven EFW pump turbine is connected to main steam lines from two SGs. The steam supply piping to the turbine driver for the A EFW pump is from the A and B main steam lines, and the steam supply piping to the turbine driver for the D EFW pump is from the C and D main steam lines. The steam supply connections are made upstream of the MSIVs. A normally open motor-operated isolation valve and a check valve are provided in each of these steam supply lines. The check valves prevent blowdown from intact SGs into a faulted SG. The isolation valves permit isolation of a line in the case of an SGTR. The steam supply to each turbine-driven EFW pump is also provided with a normally closed motor-operated EFW pump actuation valve. The opening of this valve starts the associated pump. The steam discharge from the turbine-driven EFW pumps is routed to the atmosphere.

The EFW pumps automatically start in response to an LOOP signal, an ECCS actuation signal, a main-feedwater-pumps-trip (all pumps) signal, or a low steam generator water level in any one SG.

7.6.3.2 Emergency Feedwater Pits

Two 50%-capacity EFW pits are provided. The EFW pits are completely enclosed stainless-steel-lined structures that do not contain any operating equipment. All components inside the pits are also constructed of stainless steel. The inside dimensions of each pit are approximately 28 ft long by 43 ft wide by 35 ft deep. No foreign-materials intrusion is anticipated. The EFW pits are filled with clean, demineralized water. Filtration is not required.

The required volume of each pit is 204,850 gal. The combined volumes of both EFW pits constitute the minimum water volume required for maintaining the plant in the hot standby condition for 8 hours and then performing a plant cooldown for 6 hours until the RHRS can start to operate.

The makeup line routed from the demineralized water storage tank to the EFW pits is used for initial water fill of the EFW pits and to provide makeup water for maintenance of pit water levels during normal plant operation. The demineralized water storage tank also provides a backup suction source for the EFW pumps. Since the combined volume in the EFW pits is sufficient to support a safe shutdown of the plant (keeping the plant at hot standby for eight hours and then performing a cooldown to RHRS entry conditions for six hours) after an accident or a transient, this backup supply is not required to be safety related. The manual isolation valves from the demineralized water storage tank to the EFW pumps are normally closed.

The suction lines from the EFW pits (each suction line serves two EFW pumps) are connected by a tie line containing two normally closed manual valves. When the two EFW pumps taking suction from the same pit are not available (on-line maintenance of one EFW pump and the failure of the other pump), the tie-line connection between the EFW pits needs to be opened. To prevent pumps from taking suction from a depleted pit in that case, the tie-line valves are required to be opened within about eight hours after EFW pumps start so that a continuous feedwater supply is available to the intact SGs.

7.6.3.3 Emergency Feedwater Control Valves

A normally open motor-operated globe control valve is provided in the EFW pump discharge line to each SG for controlling the EFW flow. The control valve preset open position is established during preoperational testing to limit the maximum flow during steam-line-break accidents. The valves receive confirmatory open signals upon receipt of an EFW actuation signal. These flow control valves also provide the function of isolating EFW to a faulted SG.

7.6.3.4 Emergency Feedwater Isolation Valves

A normally open motor-operated gate isolation valve is provided in the EFW line to each SG. These valves provide the function of isolating EFW to a faulted or ruptured SG, in response to low main steam line pressure or high SG water level. The valves receive confirmatory open signals upon receipt of an EFW actuation signal.

7.6.3.5 Turbine-Driven EFW Pump Steam Supply Isolation Valves

The EFW pump turbine steam supply isolation valves are normally open dc-motor-operated gate valves. One valve is provided in each line; each line emanates from a separate main steam line. These valves are containment isolation valves. Steam supply valve(s) are closed if required to terminate a leak or break or if an EFW pump actuation valve requires maintenance. The valves are operated from the MCR.

7.6.3.6 Turbine-Driven EFW Pump Actuation Valves

There are four normally closed EFW pump actuation dc-motor-operated valves. One valve is provided in each steam supply line to each EFW pump turbine (two per turbine). The valves automatically open upon receipt of an EFW actuation signal.

7.6.4 System Operation

7.6.4.1 Operation during Normal Plant Operation

The EFWS is not operated during plant startups and normal plant shutdowns.

The EFWS is not in operation during normal plant operation and is in standby. The EFW pit water levels are maintained at, or above, the minimum required levels. The manual valves in the suction line flow paths from the EFW pits to the EFW pumps are normally open. The EFW isolation and control valves in the pump discharge paths to the SGs are normally open.

7.6.4.2 Operation During Plant Transients and Accidents

The EFWS supply capacity is sufficient for makeup during hot standby conditions and during a cooldown of the plant following a transient or accident condition. The EFW pumps are aligned to supply water from the EFW pits. The EFW pumps are started by one of the EFW actuation signals: LOOP signal, ECCS actuation signal, main-feedwater-pumps-trip (all pumps) signal, or low steam generator water level in any one SG. During a transient or accident, the operator controls the EFW flow rates to the SGs to maintain acceptable SG levels. Once the SG water levels have been restored to normal values, the EFW flow rates can be reduced by manually throttling the EFW flow control valves from the MCR.

The EFWS is designed to limit the maximum amount of feedwater that can feed into a failed SG in order to prevent potential SG overfilling, or to prevent excessive containment pressurization following an MSLB. The maximum open positions of the EFW flow control valves are set during preoperational testing to limit the maximum EFW pump runout flow rate to an SG.

With one EFW pump out of service for maintenance and the failure of another EFW pump, at least two of the four EFW pumps are available to provide feedwater flow to the SGs.

Loss of Off-Site Power: All EFW pumps automatically start in response to an LOOP. Even in the case of a single active failure, three EFW pumps are available; they satisfy plant safety requirements for maintaining water levels in the SGs.

Upon an LOOP, the main feedwater pumps trip, and the water levels of the SGs initially lower. They recover gradually following initiation of EFW flow. To maintain adequate water levels in the SGs, the EFW flow rates are manually controlled by the operator from the MCR.

Loss of Main Feedwater: The operation of the EFWS during a loss of main feed water is similar to that for the LOOP event discussed above.

Loss-of-Coolant Accident: The EFWS adequately performs heat removal during a small-break LOCA while the reactor coolant system is filled with water by the safety injection system and natural circulation occurs. During this event, the EFW flow required approaches that required during a loss of main feedwater. As the size of the LOCA increases, the flow required from the EFWS decreases because the safety injection flow removes more decay heat from the core. During large-break LOCAs safety injection flow removes decay heat, and no EFW flow is required.

Feedwater Line Break: The postulated FLB assumes that the main feedwater piping between an SG and its associated main feedwater check valve ruptures during normal plant operation. The water inventory in the faulted SG is depleted as main feedwater and EFW spill out of the break, resulting in the reduction of heat removal by the SGs and leading to a temperature increase of the reactor coolant. Hence, it is necessary to isolate the faulted SG and to supply EFW to the intact SGs.

The EFW pumps automatically start following an FLB. Upon detection of a main steam pressure decrease in the faulted loop, the faulted loop is automatically isolated, and continuous EFW flow is supplied to the intact SGs.

Main Steam Line Break: The most limiting accident of the spectrum of MSLBs is the double-ended rupture of a main steam line, occurring at zero power. The accident results in a severe cooldown transient. The EFWS is assumed to provide the maximum SG feedwater flow rate, because that makes the cooldown most severe, until the affected SG is isolated. The EFWS flows to the SGs, especially the flow to the faulted SG, must be limited. The flow from the EFW line to the faulted SG is isolated automatically as described in the FLB accident analysis. The EFW function is not needed during the mitigation of the MSLB accident.

Station Blackout (SBO): During an SBO the motor-driven EFW pumps are inoperable because there is no ac power. Both turbine-driven EFW pumps are available because the pump actuation valves are supplied with dc power from Class 1E batteries with two-hr capacities. EFW flow control is also available because the EFW flow control valves are also powered by the Class 1E batteries. In addition, within one hour after the SBO occurrence, at least one alternate ac (AAC) gas turbine generator (GTG) is started, which supports the operation of one turbine-driven EFW pump's area air handling unit and thus ensures the integrity of the pump. Further, after the AAC-GTG is started, charging of Class 1E batteries is resumed; therefore, at least one turbine-driven EFW pump continues to operate beyond the first hour after SBO initiation and is independent of any other ac power source.

Anticipated Transient without Scram: The acceptance criteria for an ATWS are to provide adequate heat removal such that the maximum RCS pressure is limited to less than the emergency stress limit. For this event, the EFWS is actuated by the diverse actuation system.

Steam Generator Tube Rupture (SGTR): During an SGTR the EFW pumps automatically start on receipt of an ECCS actuation signal. Upon detection of a water level increase in the ruptured SG, the EFW isolation valve to that SG is automatically closed.

The emergency operating procedures provide additional details for operator actions during the accident conditions.

Table 7-1 Significant Design Features and Performance Characteristics for Major Steam and Power Conversion System Components

Nuclear steam supply system, rated power operation

Rated NSSS power (MWt)	4,466
Steam generator outlet pressure (psig)	957
Steam generator inlet feedwater temperature (°F)	456.7
Maximum steam generator outlet steam moisture (%)	0.1
Steam generator outlet steam temperature (°F)	541.2
Quantity of steam generators	4
Total steam flow rate from steam generator (lb/hr)	20,200,000

Turbine

Output (MW_e)	1,625 (Note)
Turbine type	Tandem-compound, 6-flow, 74-in last-stage blade
Turbine elements	1 double flow high pressure, 3 double flow low pressure
Operating speed (rpm)	1,800

Note: Output is based on main condenser pressure of 2.6 inch-HgA

Table 7-2 Turbine-Generator and Auxiliaries Design Parameters

Manufacturer Mitsubishi Heavy Industries, Ltd.	
Turbine	
Type	Tandem compound six exhaust flow
Number of elements	4 (one HPT and three LPTs)
Last-stage blade length (in.)	74
Operating speed (rpm)	1,800
Design condensing pressure (in. HgA)	1.5
Generator	
Expected generator output at 100% NSSS output (kW)	1,700,000
Power factor	0.9
Generator rating (kVA)	1,900,000
Hydrogen pressure (psig)	75
Moisture separator/reheater	
Moisture separator	Chevron vanes
Reheater	U-tube
Number	2 shell
Stages of reheating	2
Feedwater heating system	
Number of stages	7 (2 HP heaters, Deaerator and 4 LP heaters)

Table 7-3 Main Steam Supply System Design Data

Maximum calculated steam flow

Per steam generator	5,050,000 lb/hr
Total	20,200,000 lb/hr

Operating conditions

Rated power, pressure, (psia)	972.0
Rated power, temperature, (°F)	541.2
No load (hot standby) pressure, (psia)	1,107
No load (hot standby) temperature, (°F)	557.0
Allowable pressure drop from steam generator to turbine stop at full plant load, (psi)	41.3

Design conditions

Design pressure, (psig)	1,185
Design temperature, (°F)	568

Table 7-4 Main Steam System Valves (Sheet 1 of 3)

Main Steam Safety Valve

Number of valves per main steam line	6
Total number of valves	24
Relieving capacity per valve	884,000 (lb/hr) at design pressure
Relieving capacity per main steam line	5,304,000 (lb/hr) at design pressure
Total relieving capacity	21,216,000 (lb/hr) at design pressure
Valve type	Spring type
Valve size	6 (in)
Design pressure	1,185 (psig)
Design temperature	568 (°F)
Design code	ASME Section III, Class 2
	Seismic category I

Valve number	Set pressure (psig)	Relieving capacity (lb/hr)
MSS- SRV-509 (A,B,C,D)	1,185	884,000
MSS-SRV-510 (A,B,C,D)	1,215	906,000
MSS-SRV-511 (A,B,C,D)	1,244	928,000
MSS-SRV-512 (A,B,C,D)	1,244	928,000
MSS-SRV-513 (A,B,C,D)	1,244	928,000
MSS-SRV-514 (A,B,C,D)	1,244	928,000

Main Steam Relief Valve

Number per main steam line	1
Total number of valves	4
Valve size	6 (in)
Design capacity per valve	531,000 (lb/hr) at 1,150 (psig)
Total	2,121,000 (lb/hr) at 1,150 (psig)
Design pressure	1,185 (psig)
Design temperature	568 (°F)
Design code	ASME Section III, Class 2 Seismic category I
Actuator	Air-operated, modulating

Table 7-4 Main Steam System Valves (Sheet 2 of 3)

Main steam depressurization valve

Number per main steam line	1
Total number of valves	4
Valve size	6 (in)
Design capacity per valve	9.57×10^4 (lb/hr) at 125 (psia)
Total	38.3×10^4 (lb/hr) at 125 (psia)
Design pressure	1,185 (psig)
Design temperature	568 (°F)
Design code	ASME Section III, Class 2 Seismic Category I
Actuator	Motor-operated, modulating

Main Steam Relief Valve Block Valve

Number per main steam line	1
Total number of valves	4
Valve size	6 (in)
Design pressure	1,185 (psig)
Design temperature	568 (°F)
Design code	ASME Section III, Class 2 Seismic Category I
Actuator	Motor-operated

Main Steam Isolation Valves

Number per main steam line	1
Total number of valves	4
Valve size	32 (in)
Design pressure	1,185 (psig)
Design temperature	568 (°F)
Design code	ASME Section III, Class 2 Seismic Category I
Actuator	System medium actuated (using valve inside pressure)

Table 7-4 Main Steam System Valves (Sheet 3 of 3)

Main Steam Check Valves

Number per main steam line	1
Total number of valves	4
Valve size	32 (in)
Design pressure,	1,185 (psig)
Design temperature	568 (°F)
Design code	ASME Section III, Class 3 Seismic Category I
Actuator	-

Main steam bypass isolation valves

Number per main steam line	1
Total number of valves	4
Valve size	4 (in)
Design pressure	1,185 (psig)
Design temperature	568 (°F)
Design code	ASME Section III, Class 2 Seismic Category I
Actuator	Air-operated, modulating

Table 7-5 Major Feedwater Valve Design Parameters

Main feedwater regulation valves

Number of valves	4 (one valve in each loop)
Design pressure (psig)	1,850
Design temperature (°F)	480
Valve size (inch)	16

Main feedwater bypass regulation valves

Number of valves	4 (one valve in each loop)
Design pressure (psig)	1,850
Design temperature (°F)	480
Valve size (inch)	6

Main feedwater isolation valves

Number of valves	4 (one valve in each loop)
Design pressure (psig)	1,850
Design temperature (°F)	568
Valve size (inch)	16

Main feedwater check valves

Number of valves	4 (one valve in each loop)
Design pressure (psig)	1,850
Design temperature (°F)	480
Valve size (inch)	18

Steam generator water filling control valves

Number of valves	4 (one valve in each loop)
Design pressure (psig)	1,850
Design temperature (°F)	375
Valve size (inch)	3

Table 7-6 Major Condensate and Feedwater Component Design Parameters (Sheet 1 of 2)

Condensate pump	
Number	3
Type	Vertical, multistage, centrifugal
Driver	Induction ac motor
Rated flow (gpm)	12,500
Rater head (ft)	1,000
Rated power (HP)	4,500
Feedwater booster pump	
Number	4
Type	Centrifugal, horizontal
Driver	Induction ac motor (Main feedwater pump common use)
Rated flow (gpm)	16,700
Rater head (ft)	2,820 (the sum total with main feedwater pump)
Rated power (HP)	14,700 (the sum total with main feedwater pump)
Main feedwater pump	
Number	4
Type	Centrifugal, horizontal
Driver	Induction ac motor
Variable speed unit	Hydro coupling unit
Rated flow (gpm)	16,700
Rater head ()ft	2,820 (the sum total with feedwater booster pump)
Rated power (HP)	14,700 (the sum total with feedwater booster pump)
Low-pressure feedwater heater No.1	
Number	3
Type	Horizontal, single zone, shell and U-tube
Material, shell	Carbon steel
Material, tubes	Stainless steel
Heat duty (Btu/hr)	$7.4x10^8$
Low-pressure feedwater heater No.2	
Number	3
Type	Horizontal, two zone, shell and U-tube with drain cooler
Material, shell	Carbon steel
Material, tubes	Stainless steel
Heat duty (Btu/hr)	$4.6x10^8$
Low-pressure feedwater heater No.3	
Number	3
Type	Horizontal, two zone, shell and U-tube with drain cooler
Material, shell	Carbon steel
Material, tubes	Stainless steel
Heat duty (Btu/hr)	$4.4x10^8$

Table 7-6 Major Codensate and Feedwater Component Design Parameters (Sheet 2 of 2)

Low-pressure feedwater heater No.4	
Number	3
Type	Horizontal, two zone, shell and U-tube with drain cooler
Material, shell	Carbon steel
Material, tube	Stainless steel
Heat duty (Btu/hr)	$3.7x10^8$
Low-pressure feedwater heater No.5 (Deaerator with a storage tank)	
Number	1
Type	Horizontal, spray and tray type
Dissolved oxygen at exit (ppb)	5 or less
Material, shell	Carbon steel
High-pressure feedwater heater No.6	
Number	2
Type	Horizontal, two zone, shell and U-tube with drain cooler
Material, shell	Carbon steel
Material, tubes	Stainless steel
Heat duty (Btu/hr)	$1.1x10^9$
High-pressure feedwater heater No.7	
Number	2
Type	Horizontal, two zone, shell and U-tube with drain cooler
Material, shell	Carbon steel
Material, tubes	Stainless steel
Heat duty (Btu/hr)	$1.1x10^9$

Table 7-7 Design Parameters for Major Components of the Circulating Water System

Ambient design temperature	-
Design wet bulb temperature, (°F) (5% Exceedance)	76 (78 including 2 °F recirculation)
Circulating water pumps	-
Number of pumps	8
Flowrate (gpm)	164,715
Mechanical draft cooling towers	-
Number of towers	2
Number of cells in each cooling tower	30
Design inlet temperature (°F)	103.7
Design outlet temperature (°F)	88.5
Design temperature rise (°F)	15.2
CTW design approach temperature (°F)	10.5
Design flowrate (gpm)	1,290,720 plus 27,000 (for Non essential service water)

Table 7-8 Emergency Feedwater System Component Design Parameters (Sheet 1 of 3)

Motor-Driven Emergency Feedwater Pump

Number of pumps	2
Type	Horizontal, centrifugal
Capacity (gpm)	450 (including minimum flowrate)
Total dynamic head (ft)	3,120
Minimum flow rate (gpm)	50
Equipment Class	3
Design Code	ASME Section III, Class 3
Seismic Category	I

Turbine-Driven Emergency Feedwater Pump

Number of pumps	2
Type	Horizontal, centrifugal
Capacity (gpm)	550 (including minimum flowrate)
Total Dymamic Head (feet)	3,120
Minimum Flowrate (gpm)	150
Equipment Class	3
Design Code	ASME Section III, Class 3
Seismic Category	I

Table 7-8 Emergency Feedwater System Component Design Parameters (Sheet 2 of 3)

Emergency Feedwater Pit (per pit)

Number of pits	2
Pit inside dimensions, L(ft)xW(ft)xH(ft)	28 x 43 x 35
Capacity (gallons)	241,000
Required volume (gallons)	186,200
Seismic Category	I

Emergency Feedwater Control Valves

Number of valves	4
Type	Globe valve
Size (inches)	3
Design pressure (psig)	2,135
Design temperature (°F)	150
Material	Carbon steel
Design Code	ASME Section III, Class 3
Equipment Class	3
Seismic Category	I

Emergency Feedwater Isolation Valves

Number of valves	4
Type	Gate valve
Size (inch)	3
Design pressure (psig)	2,135
Design temperature (°F)	150
Material	Carbon steel
Design Code	ASME Section III, Class 2
Equipment Class	2
Seismic Category	I

Table 7-8 Emergency Feedwater System Component Design Parameters (Sheet 3 of 3)

Turbine-driven EFW pump main steam-line steam isolation valves

Number of valves	4
Type	Gate valve
Size (inches)	8
Design pressure (psig)	1,185
Design temperature (°F)	568
Material	Carbon Steel
Design Code	ASME Section III, Class 2
Equipment Class	2
Seismic Category	I

Turbine-driven EFW pump actuation valves

Number of valves	4
Type	Globe valve
Size (inches)	8
Design pressure (psig)	1,185
Design temperature (°F)	568
Material	Carbon Steel
Design Code	ASME Section III, Class 3
Equipment Class	3
Seismic Category	I